Age- and sex-specific prevalences of diabetes and impaired glucose regulation in 13 European cohorts

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published in
Diabetes Care
2003

DOI (link to publisher)
10.2337/diacare.26.1.61

document version
Publisher's PDF, also known as Version of record

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THE DECODE STUDY GROUP

OBJECTIVE — To report the age- and sex-specific prevalences of diabetes and impaired glucose regulation (IGR) according to the revised 1999 World Health Organization criteria for diabetes in Europe.

RESEARCH DESIGN AND METHODS — A total of 13 studies from nine European countries with 7,680 men and 9,251 women aged 30–89 years were included in the data analysis.

RESULTS — In most of the study populations, the age-specific prevalences of diabetes were <10% in subjects younger than 60 years and between 10 and 20% at 60–79 years of age. Mean 2-h plasma glucose (2hPG) concentration increased linearly with age, but fasting plasma glucose (FPG) concentration did not. The increase in the prevalence of undiagnosed diabetes and IGR in the elderly was mainly a result of the large increase in 2hPG rather than FPG. Diabetes and impaired fasting glycemia defined by isolated fasting hyperglycemia was more common in men than in women 30–69 years of age, whereas the prevalence of isolated postload hyperglycemia, particularly impaired glucose tolerance, was higher in women than in men, especially in the elderly (individuals >70 years of age). More than half of the diabetes was undiagnosed in subjects younger than 50 years of age.

CONCLUSIONS — Most European populations have a moderate to low prevalence of diabetes and IGR. Diabetes and IGR will be underestimated in Europe, particularly in women and in elderly men, if diagnoses are based on fasting glucose determination alone.

Diabetes Care 26:61–69, 2003

Studies on the prevalence of diabetes in the last decades have broadened our knowledge about the impact of the disease and guided public health agencies in planning programs for diabetes care and prevention. There are, however, still problems related to the detection, diagnosis, management, and prevention of diabetes. Recently, the diagnostic cutoff value for fasting plasma glucose (FPG) has been lowered from 7.8 to 7.0 mmol/l (1,2). For epidemiological studies and for routine clinical practice, the American Diabetes Association recommended using fasting glucose testing alone, and the use of the 2-h oral glucose tolerance test (OGTT) was not recommend (2), whereas the World Health Organization (WHO) Consultation still retained the OGTT (1). The impact of the changes on the prevalence of diabetes and on the reclassification of individuals has been studied in the DECODE (Diabetes Epidemiology: Collaborative Analysis of Diagnostic Criteria in Europe) study populations (3,4). The results from the DECODE study (3,4) as well as from other studies (5–8) have clearly shown that fasting and 2-h glucose criteria do not identify the same group of individuals. Young and obese subjects are more likely to have diagnostic fasting glucose values than diagnostic 2-h glucose values (3–6,8,9).

It has been recognized that the prevalence of type 2 diabetes increases with age, especially in Europe (10,11). However, in most of the previous epidemiological studies, diabetes has mainly been defined by the 2-h glucose criteria alone (11). Whether the increase in prevalence is a consequence of increased fasting glucose or increased 2-h glucose concentrations is not known. Postload hyperglycemia reflects the acute increase in blood glucose after a glucose load, whereas fasting glucose is the glucose concentration after an overnight fast and reflects mostly hepatic glucose production. They represent physiologically different aspects of glucose metabolism and can probably be influenced differently by the aging process. This issue is of importance with regard to the improvement of diagnosis and medical care of elderly diabetic patients. The impact of sex is also an unresolved issue (10,11). In this report, the age- and sex-specific prevalence of diabetes and impaired glucose regulation (IGR), as well as the age- and sex-specific prevalence of isolated fasting or 2-h hyperglycemia, was assessed among some European populations.

RESEARCH DESIGN AND METHODS

Study population

The study populations and the methods used to recruit the participants have been reported in previous DECODE publications (3,4). Briefly, information on diabetic history and data on glucose measurements at fasting and 2 h after a standard 75-g OGTT were sent to the Di-

Members of the DECODE Study Group are listed in the APPENDIX.

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Received for publication 7 May 2002 and accepted in revised form 7 October 2002.

Abbreviations: 2hPG, 2-h plasma glucose; DECODE, Diabetes Epidemiology: Collaborative Analysis of Diagnostic Criteria in Europe; FPG, fasting plasma glucose; IFG, impaired fasting glycemia; IGR, impaired glucose regulation; IGT, impaired glucose tolerance; NHANES III, Third National Health and Nutrition Examination Survey; OGTT, oral glucose tolerance test; WHO, World Health Organization.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

Table 1—*Demographic data of the study population and the participation rate in the OGTT of those invited: the DECODE study*

Study cohort (Code)	Mean age [range (years)]	Participated in OGTT [*n* (%)]	Men (%)	Blood glucose sample	Fasting time	Time of blood sampling	Glucose assay method	Years of screening	Location
MONICA-Sweden 1986 (1)	47 (30–64)	553 (78)	50.6	Plasma	Overnight	7:45–10:00	Glucose oxidase	1986	Suburban
MONICA-Sweden 1990 (2)	47 (30–64)	711 (63)	47.0	Plasma	Overnight	7:45–10:00	Glucose oxidase	1990	Suburban
MONICA-Sweden 1994 (3)	52 (30–74)	903 (62)	48.4	Plasma	Overnight	7:45–10:00	Glucose oxidase	1994	Suburban
MONICA-Finland (4)	54 (40–64)	1,841 (76)	45.4	Plasma	Overnight	8:00–10:00	Glucose dehydrogenase	1992	Urban
Oulu, Finland (5)	76 (70–89)	309 (78)	38.8	Capillary	10–12 h	8:00–10:00	Glucose dehydrogenase	1992	Urban
Hoorn, Dutch (6)	62 (50–77)	2,364 (71)	46.4	Plasma	≥ 10 h	8:00–10:00	Glucose dehydrogenase	1989–1991	Urban
Newcastle, U.K. (7)	55 (30–76)	778 (91)	51.7	Plasma	Overnight	8:00–10:00	Glucose oxidase	1992–1994	Urban
MONICA-Poland (8)	58 (44–73)	359 (81)	47.9	Serum	12 h	8:00–11:00	Glucose oxidase	1992–1993	Urban
Cremona, Italy (9)	58 (40–89)	1,672 (87)	44.0	Plasma	≥ 12 h	8:30–10:30	Glucose oxidase	1990–1991	Urban
Viva, Spain (10)	50 (34–69)	1,948 (72)	45.2	Plasma	Overnight	8:00–9:00	Glucose oxidase	1996–1997	Urban and rural
Catalonia, Spain (11)	54 (30–89)	1,835 (93)	42.3	Capillary	12 h	9:00–11:00	Refractometric	1994	Urban
Guia, Spain (12)	55 (30–89)	588 (100)	44.6	Plasma	12 h	8:00–10:00	Glucose oxidase	1997	Island
Malta (13)	49 (30–87)	1,745 (73)	43.2	Capillary	Overnight	Morning	Glucose oxidase	1981	Island
Total	54 (30–89)	15,606	45.4						

abetes and Genetic Epidemiology Unit of the National Public Health Institute in Helsinki, Finland, for collaborative analyses. The inclusion criteria for the current study are *1*) population-based studies, 2) studies performed after 1980, *3*) studies including both men and women, *4*) at least two decades of age, and *5*) a standard 2-h 75-g OGTT in the morning after an overnight fast for at least 10 h according to WHO recommendations (12,13).

A total of 15,606 subjects (7,083 men and 8,523 women) who had no prior history of diabetes and 1,325 subjects (597 men and 728 women) who had a prior history of diabetes, from 13 studies in nine European countries, met the inclusion criteria for the current data analysis. The age range was 30–89 years. Demographic characteristics and information on the glucose tests for each study cohort are shown in Table 1. Age ranges and sample sizes varied between studies, but the age distribution was similar for men and women in each cohort. The proportion of female participants was slightly higher in most of the studies. The participation rate in the 2-h OGTT varied from 62 to 100%. Before data analysis, glucose concentrations of different kinds of blood specimens were all transformed to plasma glucose concentrations (APPENDIX).

Classification of glucose abnormality

Subjects who had a prior history of diabetes were classified as having previously diagnosed diabetes. Other subjects were classified according to the 1999 WHO recommendations for the diagnosis of diabetes (1). Classifications of diabetes, impaired glucose tolerance (IGT), and normal glucose tolerance were made according to 2-h plasma glucose (2hPG) concentrations of ≥11.10, 7.80–11.09, and <7.80 mmol/l, respectively. FPG concentrations of ≥7.00, 6.10–6.99, and <6.10 mmol/l classified subjects into diabetes, impaired fasting glycemia (IFG), and normal fasting glucose. IGR according to the WHO 1999 recommendations (1) is either IGT or IFG.

Statistical analysis

Mean FPG and 2hPG concentrations were calculated for subjects who had no prior history of diabetes by age-group, for populations with at least five 10-year age-groups. The age- and sex-specific prevalences of diabetes were calculated

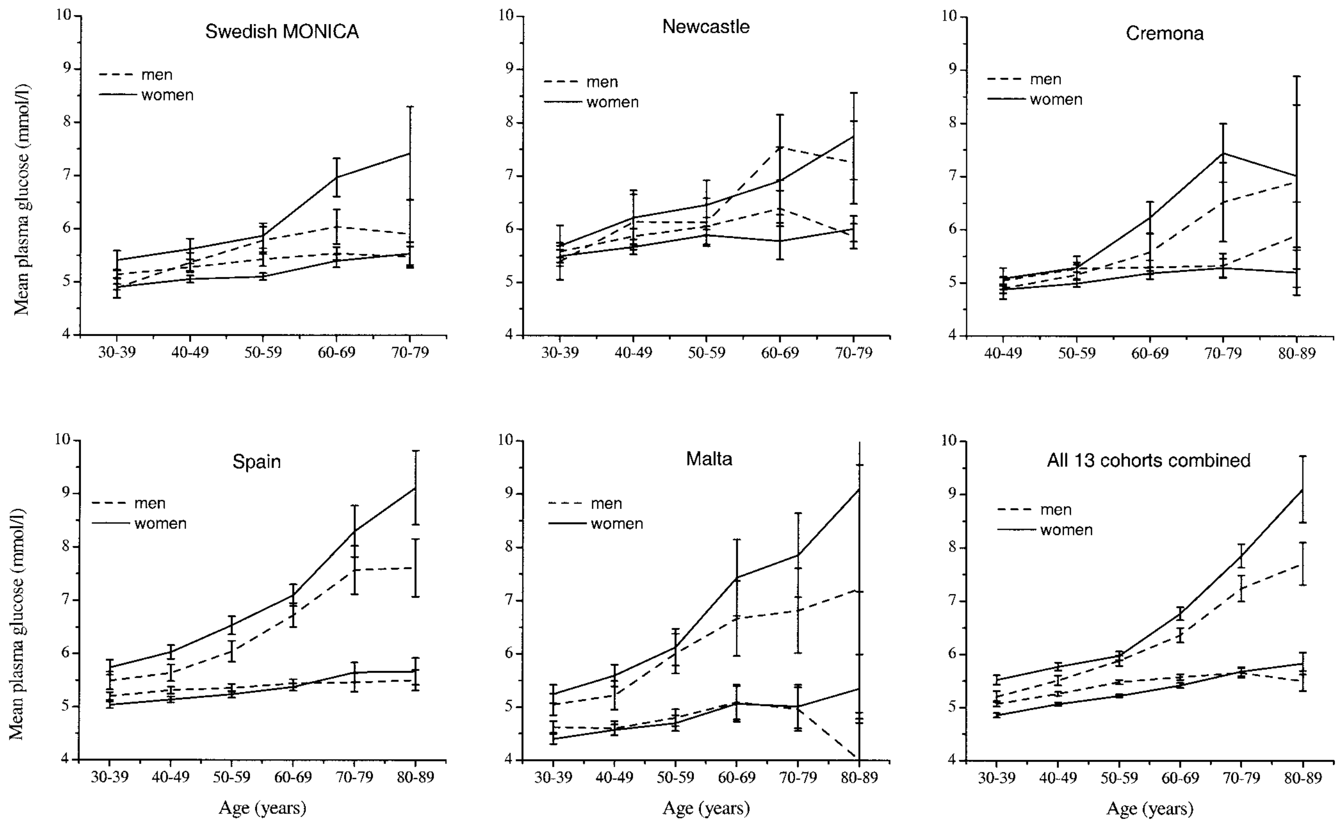

Figure 1—*Mean fasting (the two lower lines) and 2-h (the two upper lines) plasma glucose concentrations and their 95% CIs (vertical bars) for the five populations with at least five 10-year age intervals and for all 13 cohorts combined. The three Swedish cohorts were combined as one population, as were the three Spanish cohorts.*

for six 10-year age intervals, from 30 up to 89 years, separately for subjects with and without diagnosed diabetes. The prevalence of diagnosed diabetes (Pkn) was calculated by dividing the number of diagnosed cases by the total number of subjects who had responded to the questions on the prior history of diabetes. Because there were nonparticipants in the OGTTs, the prevalence of undiagnosed diabetes = [(undiagnosed cases identified by the OGTTs/the number of individuals who attended the OGTTs) × (1 − Pkn)]. The same rule was applied when calculating the prevalence of IGR. A χ^2 test was used to measure the differences in prevalence between men and women.

RESULTS

Age- and sex-specific plasma glucose concentration

The mean 2hPG concentration rose with age and increased more after 50 years of age in each study population (Fig. 1). Women had a significantly higher mean 2hPG concentration than men in each age-group except in the fifth decade. The difference between men and women became larger in subjects older than 70 years of age. In men, the mean FPG concentration increased with age up to 69 years of age; thereafter, there was no further increase, whereas it rose with age in women (Fig. 1). The mean FPG concentration was higher in men than in women at 30–69 years of age; after 70 years of age, it was higher in women than in men.

Age- and sex-specific prevalence of diabetes

The age-specific prevalence of diabetes rose with age up to the seventh and eight decades in both men and women in each study population (Table 2, Fig. 2*A*). In most of the studies, the prevalence was <10% in subjects younger than 60 years of age and between 10 and 20% at 60–79 years of age. They were higher in Malta than in other populations, in each age-group for both sexes, and the prevalence of known diabetes was particularly higher. The prevalence of diabetes was also higher in elderly Finnish women in Oulu and in elderly Spanish women in Guia, compared with most of the other populations.

As shown in Fig. 2*A*, the prevalence of isolated postload hyperglycemia (2hPG ≥11.1 mmol/l and FPG <7.0 mmol/l) increased more with age than isolated fasting hyperglycemia (FPG ≥7.0 mmol/l and 2hPG <11.1 mmol/l), especially in women.

Age- and sex-specific prevalence of IGR

The prevalence of IGR rose with age in each study (Table 3 and Fig. 2*B*). In most of the study populations, the prevalence of IGR was <15% at 30–59 years of age and between 15 and 30% after 60 years of age. In each age-group, they were higher in Newcastle in the U.K., Poland, and Catalonia in Spain, compared with other populations. The elderly Finnish men and women in Oulu had the highest prevalence of IGR.

The prevalence of IGT increased linearly with age, but the prevalence of IFG

Table 2—*Prevalences of previously diagnosed and undiagnosed diabetes defined by 2hPG and FPG criteria in men and women in the DECODE cohorts*

		Undiagnosed diabetes (mmol/l)									
		2hPG ≥ 11.1 and FPG < 7.0		2hPG < 11.1 and FPG ≥ 7.0		2hPG ≥ 11.1 and FPG ≥ 7.0		Diagnosed diabetes		Total diabetes	
Cohort	Age (years)	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
MONICA 1986, Sweden	30–39	1.2	2.6	0	0	2.4	0	0.9	0.5	4.5	3.1
	40–49	0	1.3	0	0	0	0	2.5	1.5	2.5	2.8
	50–59	0	2.3	1.2	0	1.2	0	5.8	1.4	8.1	3.7
	60–64	2.3	5.6	2.3	0	0	0	15	9	19.6	14.6
MONICA 1990, Sweden	30–39	0	1.0	0	1.0	0	0	1.6	0.5	1.6	2.5
	40–49	0	0	1.0	0.9	0	0.9	2	1	3.0	2.8
	50–59	0	1.7	1.1	0	1.1	0.9	5.5	3.8	7.6	6.4
	60–64	0	3.7	3.2	1.8	3.2	0	7.2	5.9	13.6	11.4
MONICA 1994, Sweden	30–39	0	0	1.2	0	0	0	0.6	1.0	1.8	1.0
	40–49	1.9	1.9	0.9	1.0	0.9	0	1.5	1.5	5.3	4.4
	50–59	1.0	2.8	1.0	0.9	0	0.9	2.6	1.5	4.5	6.1
	60–69	3.1	5.7	2.3	1.6	2.3	2.4	6.1	4.5	13.9	14.3
	70–74	0	2.4	2.8	0	0	2.4	13.9	8.3	16.7	13.1
MONICA, Finland	40–49	1.2	1.2	1.9	1.8	0	0	1.6	0.8	4.7	3.8
	50–59	1.2	0.9	3.6	1.5	1.6	0.7	3.2	3.0	9.6	6.0
	60–64	1.2	1.7	2.3	0.9	1.7	0.9	4.1	4.4	9.2	7.8
Oulu, Finland	70–79	7.2	5.3	7.2	8.3	5.4	3.6	17.1	17.2	36.9	34.3
	80–89	3.6	9.1	7.1	6.1	0	13.7	0	25.8	10.7	54.6
Hoom, Dutch	50–59	1.5	0.7	2.2	1.8	2.1	0.5	2.2	1.4	8.0	4.4
	60–69	1.2	2.5	2.4	1.9	3.4	3.1	3.8	5.0	10.7	12.5
	70–77	2.9	4.3	3.5	2.6	5.7	4.7	4.0	8.1	16.0	19.7
Newcastle, U.K.	30–39	0	0	0	0	0	0	0	0	0	0
	40–49	1.2	1.2	4.8	0	2.5	1.2	1.3	1.3	9.7	3.7
	50–59	1.0	0	6.7	3.0	2.8	2.0	3.1	3.0	13.6	8.0
	60–69	1.0	2.1	7.9	6.4	4.9	2.1	3.3	3.3	17.1	13.9
	70–76	3.4	6.0	3.4	4.0	3.4	2.0	6.3	0	16.4	12.0
MONICA, Poland	44–49	2.4	0	4.9	2.6	0	0	2.1	0	9.5	2.6
	50–59	3.6	3.9	5.4	0	0	1.3	0	2.0	9.0	7.2
	60–69	7.4	4.8	2.9	1.6	2.9	0	2.5	11.3	15.7	17.7
	70–73	0	10.8	0	0	0	0	5.6	8.3	5.6	19.1
Cremona, Italy	40–49	0	0	0.9	0	0	0.9	3.2	1.2	4.1	2.1
	50–59	1.5	0.7	0.8	0	0.4	0.7	5.6	3.7	8.2	5.0
	60–69	1.9	1.8	2.4	0.7	1.0	1.1	12.9	9.4	18.2	13.0
	70–79	1.2	6.6	0	1.3	4.7	2.6	11.2	10.1	17.1	20.6
	80–89	0	3.0	8.5	0	0	3.0	6.7	28.9	15.2	34.9
Viva, Spain	34–39	0	1.1	0	0	0	0	0.4	2.2	0.4	3.3
	40–49	1.3	1.5	2.6	0.5	0.7	0.3	0.4	2.6	5.0	4.8
	50–59	3.0	1.9	1.9	0.3	0.8	1.6	1.8	3.6	7.5	7.4
	60–69	2.5	4.0	1.8	1.5	1.8	0.5	4.3	4.2	10.4	10.3
Catalonia, Spain	30–39	1.5	0.5	0.7	0.5	0	0	1.3	0.3	3.5	1.3
	40–49	0	1.4	2.4	1.8	0.6	0	1.7	1.7	4.6	4.8
	50–59	2.0	1.2	0.6	0.4	0	0	8.6	7.4	11.3	9.0
	60–69	4.0	5.9	1.3	1.5	1.3	0.4	12	17.5	18.6	25.3
	70–79	5.3	7.6	0.9	2.6	0	0.9	13.5	19.8	19.6	30.9
	80–89	7.3	10.2	2.5	0	0	3.4	11.9	11.1	21.7	24.7
Guia, Spain	30–39	0	0	0	0	0	0	0	0	0	0
	40–49	0	0	1.8	1.3	1.8	0	7.0	3.8	10.6	5.2
	50–59	3.9	2.8	2.0	1.4	0	2.8	12.2	10.9	18.2	17.9
	60–69	3.8	5.1	0	0	3.8	1.3	15.8	19.3	23.4	25.7
	70–79	7.1	11.6	0	0	1.7	0	13.3	32.2	22.2	43.8
	80–89	0	18.7	0	0	0	6.2	15.6	31.6	15.6	56.5
Malta	30–39	1.4	0.3	1.9	0.7	1.4	0	0.9	4.6	5.6	5.6
	40–49	1.1	1.6	2.2	1.2	1.1	0	7.1	4.5	11.6	7.4
	50–59	3.2	1.9	2.2	1.1	2.2	1.9	14.1	18.9	21.7	23.8
	60–69	0.7	5.4	2.0	1.8	4.7	2.4	25.5	36.3	32.9	45.8
	70–79	3.6	7.6	4.8	0	2.4	2.1	32.1	37.6	42.8	47.3
	80–87	5.9	8.3	0	4.2	0	8.3	35.3	33.3	41.2	54.2
Total	30–39	0.7	0.6	0.7	0.4	0.6	0*	1.0	1.5	2.9	2.5
	40–49	0.8	1.1	2.0	1.0*	0.6	0.2	2.1	1.8	5.4	4.2*
	50–59	1.7	1.3	2.3	1.0†	1.3	0.9	4.8	4.6	10.1	7.8*
	60–69	2.1	3.6‡	2.5	1.6	2.5	1.6	8.5	9.3	15.5	16.1
	70–79	4.0	6.1*	3.0	2.9	3.4	2.8	12.9	15.4	23.4	27.3*
	80–89	3.9	9.2*	3.2	3.1	0	8.6‡	12.4	22.4*	19.5	43.3‡

Data are %. $^*P < 0.05$, $^\dagger P < 0.001$, $^\ddagger P < 0.01$, for the difference between men and women.

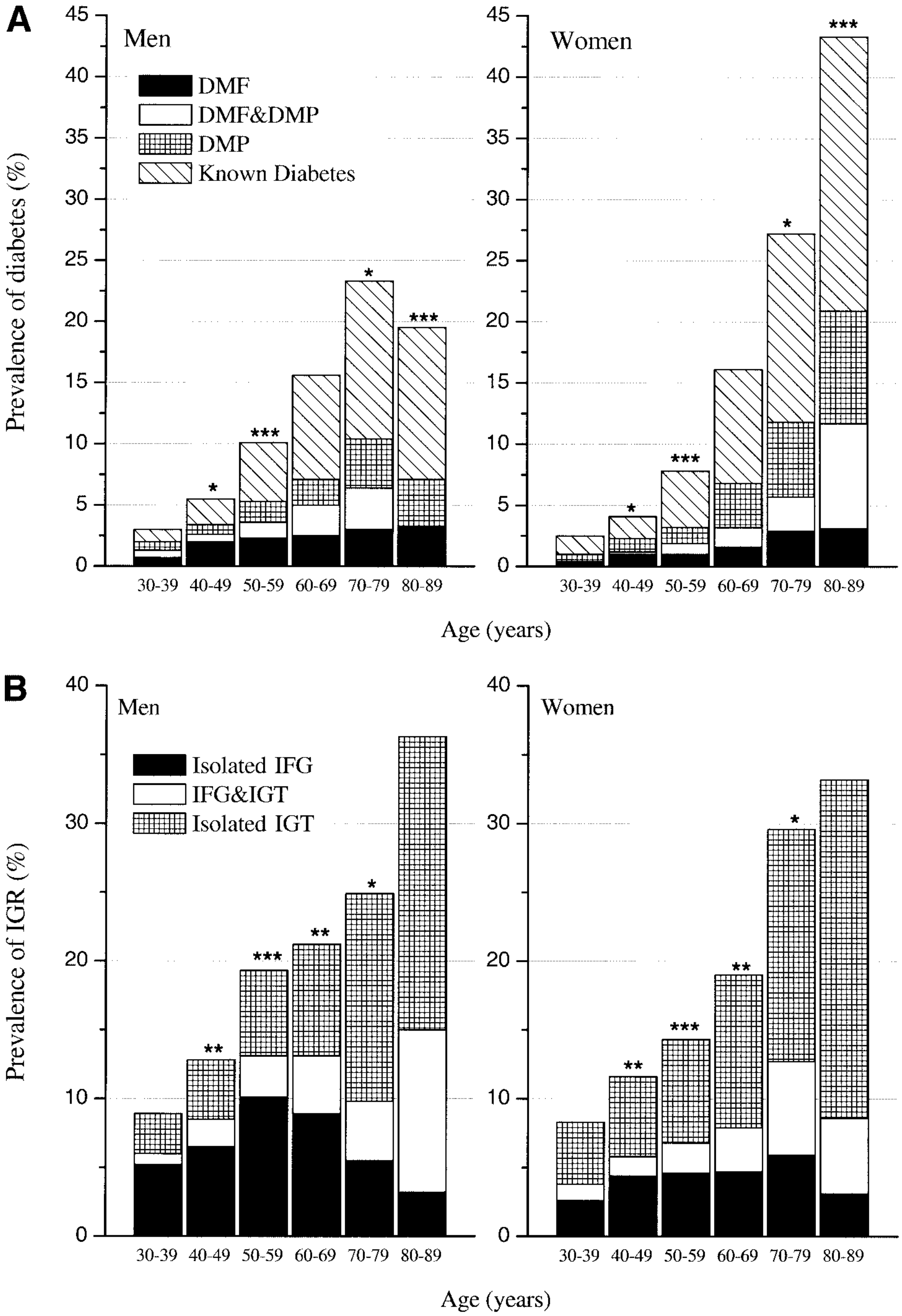

Figure 2—*Age- and sex-specific prevalence of diabetes (A) and IGR (B) for all studies combined. DMF: Diabetes determined by FPG ≥7.0 mmol/l and 2hPG <11.1 mmol/l; DMP: Diabetes determined by 2hPG ≥11.1 mmol/l and FPG <7.0 mmol/l; DMF&DMP: Diabetes determined by FPG ≥7.0 mmol/l and 2hPG ≥11.1 mmol/l; Isolated IFG: FPG 6.1–6.9 mmol/l and 2hPG <7.8 mmol/l; Isolated IGT: 2hPG 7.8–11.0 mmol/l and FPG <6.1 mmol/l; IFG&IGT: FPG 6.1–6.9 mmol/l and 2hPG 7.8–11.0 mmol/l.* *P < 0.05, **P < 0.01, ***P < 0.001, *for the difference in the total prevalence between men and women.*

did not (Fig. 2*B*). The concordance between the two was poor.

Sex difference in prevalence of diabetes, IFG, and IGT

In most of the study cohorts, the age-specific prevalences of previously undiagnosed diabetes and IGT defined by isolated postload hyperglycemia were higher in women than in men, but the prevalences of undiagnosed diabetes and IFG diagnosed by isolated fasting hyperglycemia were higher in men than in women (Tables 2 and 3). The sex difference in the prevalence of undiagnosed diabetes and IFG defined by isolated fasting hyperglycemia was statistically significant in subjects younger than 70 years of age. IGT was more prevalent in women than in men in all age-groups, although significantly different only in subjects younger than 70 years of age (Table 3). Undiagnosed diabetes defined by isolated postload hyperglycemia was more prevalent in women than in men after 60 years of age (Table 2).

The prevalence of previously diagnosed diabetes did not differ between men and women, except in the people aged 80 years or older, where the prevalence was higher in women (Table 2). The total prevalence of diabetes (Fig. 2*A*) was higher in men 40–59 years of age but

Table 3—Prevalences of IGT, IFG, and IGR defined according to 2hPG and FPG criteria (mmol/l) in men and women in the DECODE cohorts

		Isolated IGT		Isolated IFG		IGT and IFG		IGR	
		2hPG 7.8–11.0 and FPG < 6.1		2hPG < 7.8 and FPG 6.1–6.9		2hPG 7.8–11.0 and FPG 6.1–6.9		IGT or/and IFG	
Cohort	Age (years)	Men	Women	Men	Women	Men	Women	Men	Women
MONICA 1986, Sweden	30–39	4.8	9.2	1.2	1.3	0	0	5.9	10.4
	40–49	7.4	7.6	2.4	0	0	1.3	9.8	8.9
	50–59	8.1	11.4	1.1	2.3	0	1.2	9.2	14.9
	60–64	2.3	11.0	4.6	2.7	2.3	0	9.2	13.7
MONICA 1990, Sweden	30–39	0	3.9	4.5	0	0	1.0	4.5	4.9
	40–49	2.0	6.1	14.6	0.9	2.0	0	18.5	7.0
	50–59	6.4	6.9	7.6	6.1	0	0.9	14.0	13.9
	60–64	0	11.1	12.8	11.1	0	3.7	12.8	25.9
MONICA 1994, Sweden	30–39	2.5	3.9	2.5	0	0	1.0	5.0	4.9
	40–49	0.9	2.9	2.8	3.8	3.8	1.9	7.6	8.6
	50–59	5.8	9.3	13.6	1.9	4.9	0.0	24.4	11.2
	60–69	7.0	13.1	7.0	2.4	3.1	1.6	17.1	17.1
	70–74	13.9	16.9	5.6	4.8	0	14.5	19.4	36.2
MONICA, Finland	40–49	4.6	4.9	11.9	6.1	3.4	0.9	20.0	11.8
	50–59	7.4	5.3	15.6	4.3	6.6	4.1	29.5	13.7
	60–64	7.4	11.6	14.3	4.3	5.2	5.5	26.9	21.4
Oulu, Finland	70–79	18.9	25.4	7.2	7.7	7.2	15.4	33.3	48.5
	80–89	35.7	25.7	7.1	6.1	21.4	6.1	64.2	37.9
Hoorn, Dutch	50–59	3.5	3.8	8.8	5.7	2.2	1.4	14.6	10.9
	60–69	5.8	9.9	12.9	5.6	3.1	2.5	21.7	18.0
	70–77	11.3	11.9	6.8	8.1	3.9	5.1	22.1	25.2
Newcastle, U.K.	30–39	3.0	3.6	11.9	9.1	4.5	1.8	19.4	14.5
	40–49	6.1	7.1	15.8	10.7	3.6	2.4	25.5	20.1
	50–59	1.9	8.0	31.4	16.0	2.8	6.0	36.1	30.0
	60–69	7.9	8.5	13.8	10.6	17.8	5.3	39.6	24.5
	70–76	17.1	12.0	11.9	8.0	3.4	14.0	32.3	34.0
MONICA, Poland	44–49	2.4	15.4	14.7	5.1	4.9	7.7	22.0	28.2
	50–59	14.3	20.7	16.1	1.3	8.9	3.8	39.3	25.8
	60–69	19.2	22.6	10.3	3.2	4.4	4.9	33.9	30.7
	70–73	0	16.1	18.9	0	0	10.8	18.9	27.0
Cremona, Italy	40–49	3.1	4.0	1.3	0.4	0.5	0.9	4.9	5.2
	50–59	3.4	3.3	7.5	0.7	1.5	1.2	12.4	5.2
	60–69	7.3	8.0	3.4	2.5	1.5	2.2	12.2	12.7
	70–79	9.5	17.7	2.4	0.6	3.6	1.3	15.5	19.7
	80–89	25.5	20.8	0	0	17.0	0	42.5	20.8
Viva, Spain	34–39	3.8	2.1	9.6	2.5	0	1.6	13.3	6.2
	40–49	5.2	3.3	4.9	4.0	1.3	1.3	11.4	8.6
	50–59	9.0	10.9	4.9	5.1	0.8	1.3	14.7	17.3
	60–69	7.9	9.5	4.9	4.0	3.1	2.5	15.9	16.0
Catalonia, Spain	30–39	4.3	7.4	7.2	4.4	1.5	2.5	13.0	14.3
	40–49	6.5	9.3	5.9	9.6	3.5	2.8	15.9	21.7
	50–59	9.3	12.2	11.3	9.4	5.3	4.9	26.0	26.5
	60–69	14.9	13.8	7.9	5.9	5.3	4.9	28.1	24.6
	70–79	22.9	17.7	3.5	9.3	7.1	6.7	33.6	33.8
	80–89	12.2	30.8	4.9	3.4	7.3	6.8	24.5	41.0
Guia, Spain	30–39	6.3	7.5	6.3	3.8	0	1.3	12.6	12.6
	40–49	5.4	11.8	3.5	2.6	1.8	2.6	10.7	17.0
	50–59	14.0	19.5	11.9	0.0	3.9	4.2	29.8	23.7
	60–69	11.5	15.3	9.6	3.9	3.8	5.1	24.8	24.3
	70–79	19.4	11.6	3.6	3.9	3.6	0	26.5	15.5
	80–89	16.9	12.5	0	0	13.5	12.5	30.4	24.9
Malta	30–39	0.9	3.0	1.4	2.0	0.9	0.3	3.2	5.2
	40–49	2.7	5.4	2.2	2.2	0	0.3	4.9	7.9
	50–59	5.9	7.1	1.4	1.5	0	0.4	7.3	8.9
	60–69	6.7	8.9	1.3	2.4	3.4	0	11.4	11.3
	70–79	10.7	17.2	1.2	3.2	1.2	0	13.2	20.5
	80–87	23.6	20.9	0	0	0	4.2	23.6	25.1
Total	30–39	2.9	4.5*	5.2	2.6†	0.8	1.2	8.9	8.3
	40–49	4.3	5.8*	6.5	4.4†	2.0	1.4	12.7	11.6†
	50–59	6.2	7.5*	10.1	4.6‡	3.0	2.2	19.2	14.3‡
	60–69	8.1	11.1†	8.9	4.7‡	4.2	3.2	21.2	19.0‡
	70–79	15.1	16.9	5.5	5.9	4.3	6.8*	24.8	29.6
	80–89	21.3	24.6	3.2	3.1	11.8	5.5	36.2	33.2

Data are %. *$P < 0.05$, †$P < 0.01$, ‡$P < 0.001$, for the difference between men and women.

lower in men over 70 years of age, compared with women. The similar age and sex pattern for the prevalence of IGR was also observed (Fig. 2*B*).

Proportion of previously undiagnosed diabetes

The percentage of subjects with undiagnosed diabetes varied with age and sex. For all studies combined, the proportions of undiagnosed diabetic cases were 0.70, 0.60, 0.50, 0.50, 0.40, and 0.40 in men and 0.39, 0.58, 0.41, 0.42, 0.43, and 0.48 in women, respectively, at 30–39, 40–49, 50–59, 60–69, 70–79, and 80–89 years of age. In men, the proportion was high in young age-groups and decreased with age, whereas there was not a clear prevalence pattern with age in women.

CONCLUSIONS — The prevalences of diabetes and IGT according to the WHO 1985 criteria have been reported previously for all of the individual studies (14–24), but the prevalence of diabetes and IGR according to the revised WHO 1999 criteria (1) have not been fully reported. In the current article, the age- and sex-specific prevalences of diabetes and IGR as well as their components according to the revised diagnostic criteria were investigated in each of the individual studies and in all studies combined. We found that the 2hPG concentration increased linearly with age, but the FPG concentration did not. The increase in the prevalence of undiagnosed diabetes and IGR in the elderly population resulted mainly from the large increase in postload hyperglycemia rather than fasting hyperglycemia. In addition, we found that there was a distinct sex difference in the prevalence of diabetes, IFG, and IGT. Undiagnosed diabetes and IFG defined by isolated fasting hyperglycemia was more common in men than in women at 30–69 years of age, whereas the prevalence of isolated postload hyperglycemia was higher in women than in men and was particularly higher in the elderly population (>70 years of age).

The finding that postload hyperglycemia was more prevalent in the elderly was consistent with a recent report from the Third National Health and Nutrition Examination Survey (NHANES III) (25). In that report, however, men and women were not studied separately. Our study further revealed that postload hyperglycemia, particularly IGT, was also more prevalent in women of all ages than in men. This finding is consistent with a previous report that there are, worldwide, more women than men with IGT (11). Therefore, the prevalence of undiagnosed diabetes and IGR would be underestimated to a large extent in Europe, especially in female and elderly populations, if fasting glucose determination alone would be used, whereas the primary purpose of a population-based screening program for diabetes is to detect previously undiagnosed diabetes and IGR.

The prevalence of previously undiagnosed diabetes, according to a FPG level of $\geq$7.0 mmol/l alone, for U.S. adults aged $\geq$20 years was estimated in the NHANES III (26). At a comparable age range of 40–59 years, the prevalence of undiagnosed diabetes according to the same fasting glucose criteria was lower in most of the female populations and in about half of the male European populations, compared with the U.S. non-Hispanic white population, but they were all lower than those of Mexican American subjects.

Age- and sex-specific prevalences of diabetes (known plus unknown cases defined according to 2hPG $\geq$11.1 mmol/l) in selected populations worldwide have been assembled using aggregate data and were reported by King et al. in 1993 (11). However, in that report, only two small European studies from Poland and Finland were included, and the old WHO 1985 criteria were used (13). In the current study, age- and sex-specific prevalences of diabetes and IGR according to the recently revised WHO 1999 diagnostic criteria were reported for 13 European cohorts based on the individual data. At comparable age ranges of 30–69 years, the prevalences of diabetes, estimated using the same 2-h glucose criteria, in most of the European populations were lower than most of the other populations worldwide, but higher than those in the Bantu in Tanzania and the Chinese in Da Qing (11). About half of the male European populations had higher and half had lower prevalences of diabetes than U.S. non-Hispanic men, whereas U.S. non-Hispanic white women had higher prevalences than most of their female European counterparts in all age-groups. Europeans have a moderate to low prevalence of diabetes compared with most of the other racial and ethnic groups worldwide where age- and sex-specific prevalences of diabetes have been reported.

The ratio of prevalences of glucose abnormality between men and women has been estimated in many studies, but so far there has been no consistent trend (11,26). The previous WHO estimate (11) was based on aggregate data with age-standardized rates rather than on individual subject data with age-specific rates. The major limitation of using aggregate data is that detailed analysis using the same strategy cannot be made. In addition, an age-standardized estimate does not represent the true population prevalence because it depends not only on the actual age-specific rates in the study sample but also on the age distribution of the chosen standard population. Our study showed a clear sex pattern in the prevalence of postload hyperglycemia and the prevalence of fasting hyperglycemia. This pattern was similar to the sex patterns of the population distributions of age-specific FPG and 2hPG concentrations. The findings may be important for planning treatment strategy, designing screening programs, and improving diabetes care.

The DECODE study is based on collaborative analysis of the existing population-based databases. It is an economic and efficient way to maximize and optimize the use of survey databases. During the data analysis, the same diagnostic criteria and strategy could be used in all studies, and thus, results could be compared directly between studies. However, because the individual surveys have been carried out independently, there were differences in study design, participation rate, and classification of known diabetes and no centralized glucose assays, despite the application of uniform inclusion criteria. Nevertheless, there were many similarities between studies, such as the number of hours of fasting, the time for blood sampling, and the method for glucose assay. Moreover, the findings were also homogeneous among the DECODE populations in terms of the age-specific glucose concentrations and the sex difference in prevalence of fasting and postload hyperglycemia. This suggests the findings are valid.

In conclusion, the prevalence of diabetes and IGR in Europe was moderate to low compared with other worldwide reports. The prevalence of isolated postload hyperglycemia (diabetes and IGT) increased with age, but the prevalence of isolated fasting hyperglycemia (diabetes and IFG) did not. The former was more common in women of all ages and in elderly men, and the latter more prevalent in young and middle-aged men. Diabetes and IGR will be underestimated in Europe, particularly in women and in elderly men, if diagnosis of diabetes is based on FPG determination alone.

Acknowledgments— This analysis was carried out with the help of grants from Novartis Pharma, Basel, Switzerland, and from the Finnish Academy (grants 46558, 76502, and 77618). The DECODE study was initially funded by Novo Nordisk, Bagsvaerd, Denmark.

APPENDIX— The DECODE study was started in 1997 on the initiative of the European Diabetes Epidemiology Group.

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